CHAPTER 3. INDUSTRIAL R&D

Although government R&D budgets have recently increased, industrial laboratories still conduct the vast majority of Japan's research, funding nearly 75 percent of the total resources for R&D and employing nearly 70 percent of the research scientists and engineers (table A-4 and table 3). Until the economic recession of 1992, the annual R&D budget for the Japanese firm Hitachi alone equaled the total amount administered by the Ministry of Education (Monbusho) to university research (Barker, 1996). Large Japanese companies have built central laboratories for long-term strategic research. While academic science was in an impoverished state throughout the 1980s, corporate science flourished. Thus, corporate science dominates many fields in Japan.

The Japanese model of imported technology and adaptive R&D to rebuild its industry and technology following the devastation of World War II was very successful. Technological development was led by close cooperation between MITI and various industries. What is sometimes mistakenly perceived as "copying" from the West enabled Japan's significant industrial investment in R&D to adapt and extend technologies. The section below, Overall Industrial R&D Trends, provides some indicators of Japan's heavier industrial investment in R&D compared with that of the United States.

An important aspect of Japanese industrial R&D is to go beyond the limits of the technology—to make better and better products. For example, Japanese companies are world leaders in engineering very fine fibers, and also in bringing the purity of iron to extremely high levels. This type of research is especially appreciated in Japan. The pursuit of the extremes of a technology takes a consistency in R&D support, which Japanese industry has been willing to continue, sometimes for over 20 years, to accomplish a breakthrough (Hara, 1996). (See "*Toray Industries' Adaptive Research*" as an example of Japan's strong commitment to such research.)

Besides demonstrating a great consistency in research, Japanese industry has also provided life-long training to its scientists and engineers. Leading industries recruit very good students from high ranking universities and department chairs. Once hired, young researchers are given in-house education, attend international conferences, and are continuously in contact with academic and professional societies. Top young research scientists and engineers are encouraged to earn their doctorate through industry, called *ronbun*, or thesis doctorates. The majority of senior researchers in industry have *ronbon* doctorates; the minority of senior industrial researchers earned course-work doctorates in universities.

TORAY INDUSTRIES' ADAPTIVE RESEARCH

Toray Industries exemplify some of the corporate R&D strategies for competitiveness that have contributed to Japan's trade surplus in high technology products. Toray, a textile company established in 1923, purchased licensing agreements from Dupont (1953) for production of nylon, and from the United Kingdom (1971) for carbon fiber production.

Through 20 years of R&D in its advanced composite materials laboratories, Toray has produced carbon fiber products with the highest tensile strength in the world. Japan is now the biggest carbon fiber producer in the world, exporting half its production to the United States for use in the aircraft industry and for high quality sporting goods. When the United Kingdom sold Japan the licensing agreement for carbon fiber production, it did not envision all the large market applications of carbon fibers (Hara, 1996).

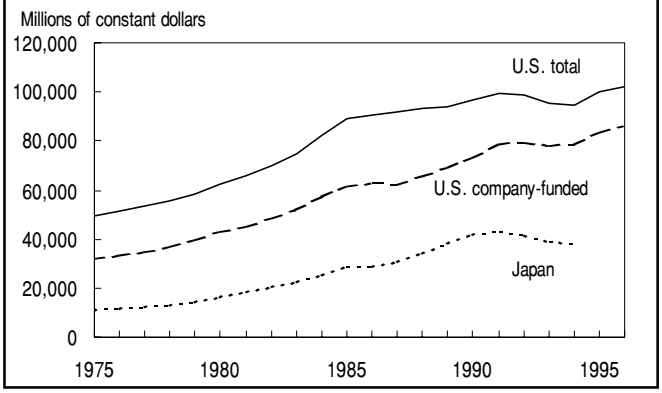
Industrial career development programs also include sending researchers to universities throughout the world—though mainly to the United States—for a period of 1–2 years as visiting researchers or doctoral students. In general, Japanese industrial researchers are sent abroad after obtaining their master's degrees, usually for 2–3 years, to top research universities that specialize in fields of particular interest to Japanese industry. For example, University of California at Irvine is often selected by Toshiba researchers for advanced training in biotechnology, machinery, and electronics, because of its close proximity to a large Toshiba factory that produces personal computers (Takayanagi, 1996).

Corporate laboratories also provide donations to leading Japanese national universities, are closely related to professors knowledgeable in specific fields of R&D, and hire their students. In some fields, such as electronics, researchers go to Japanese universities for advanced training, or to government research laboratories in Tsukuba Science City (Hara, 1996). In the past, donations of equipment and scholarship funds to universities and non-formal exchange of information have provided a loose coupling between industry and Japanese universities, but no strong involvement of university faculty in specific research projects. In contrast, professors in the United States are able to be directly employed by companies. Programs for industry—university joint projects are being established in Japan,[12] but regulations related to external payments to professors (who are civil servants) may require 2–5 years to resolve. (Takayanagi, 1996).

Overall Industrial R&D Trends

In both the United States and Japan, industrially funded R&D increased rapidly from 1975 to the peak year in 1991, followed by stagnant, or slightly declining, industrial R&D investments each year since then. Japanese industry investment in R&D rose from $11.4 billion in 1975 to $44 billion in 1991, representing an 8.9-percent average annual growth rate (table A-4). In the peak year of industrial support of R&D, 1991, private industry accounted for 78 percent of overall R&D in Japan. Industrially supported research in Japan declined an average of 3.1 percent annually from 1991–94. In the United States, industry investment in R&D rose from $32.2 billion in 1975 to $79.8 billion in 1992, representing an average-annual growth rate of 5.5 percent. In the United States, a slowdown in the economy resulted in a slight decline of industrial support of R&D in 1993–94. The average rate of decline was 1 percent over this period. More recent (preliminary) data for U.S. industrial R&D funding, however, show an expected 3.5-percent increase for 1995–96 (figure 13). The continued decline in Japanese industrial R&D stems from a prolonged economic recession.

Figure 13. National industrial R&D expenditures



See appendix tables A-4 and A-5.

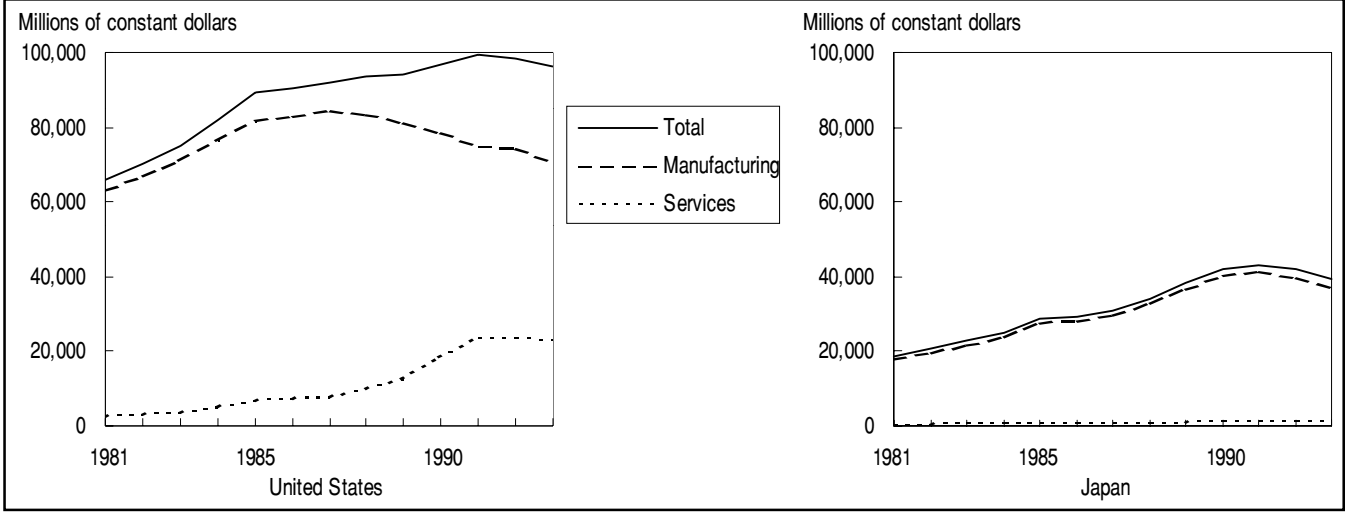
Declines in overall R&D were somewhat softened by increases in R&D in the service industries. U.S. industrial research in the manufacturing sector had strong growth in the early 1980s, level funding in the mid-1980s, and declining budgets every year since 1989. At the same time that manufacturing industries decreased their investments in R&D, service sector industries increased their R&D. In addition, part of R&D previously classified as manufacturing is now classified in service industries. By 1993, the service sector in the United States accounted for approximately one-quarter of industrial R&D (figure 14 and table A-10). In contrast, Japanese industrial R&D performance is highly concentrated in the manufacturing sector.[13]

As a percentage of Gross Domestic Product (GDP), Japanese industrial R&D doubled from 1975–90, and has declined slightly in the 1990s (table A-11). In 1994, the ratio of overall Japanese

[12] Subsequent to the Japanese student riots in the 1960s to protest industry interaction with universities, mainstream professors had little collaboration with industry. Since 1985, however, professors have again begun to collaborate with industry. Many projects are occurring, with strong industry—university collaboration.

[13] The Japanese service sector may not yet be well surveyed.

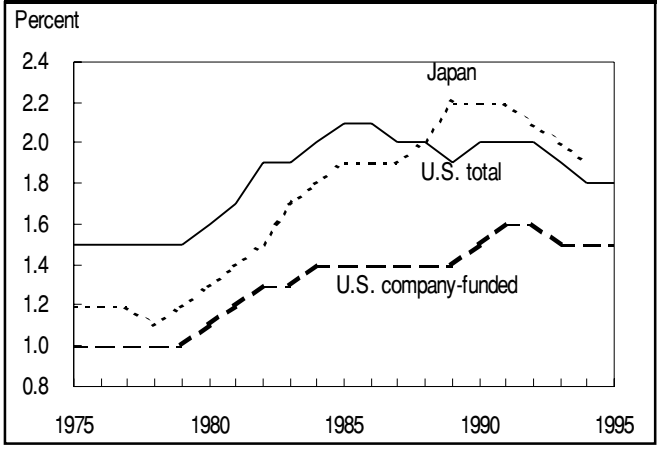
Figure 14. Industrial R&D performance, by sector



See appendix table A-10.

industrial R&D to GDP—1.9 percent—was comparable to the U.S. proportion of 1.8 percent. However, Japanese industrial R&D is almost entirely (98 percent) financed by companies themselves. This Japanese company-funded R&D as a percentage of GDP has surpassed the U.S. ratio of company-funded R&D to GDP every year since 1975. In 1994, company-funded R&D represented 1.9 percent of GDP in Japan and 1.5 percent in the United States (figure 15).

Figure 15. Industrial R&D as a percent of GDP



See appendix table A-11.

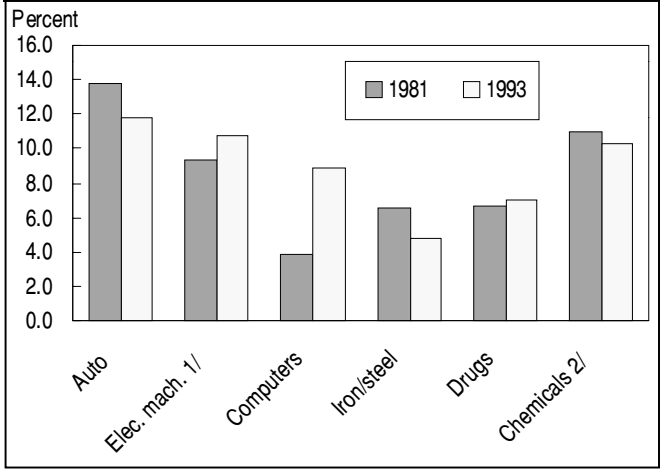
R&D Concentration in Manufacturing Industries

While Japanese manufacturing industries have maintained huge trade surpluses with neighboring countries in the region, the Asian developing economies are beginning to erode Japan's dominant economic position in many markets. In a 1994 survey, Japanese companies rated competition from Asia as one of their major concerns. Corporate R&D managers stressed that the "creation of distinctive high-value-added products through research" is one of the most important Japanese business strategies. Japan's future competitiveness in the region is viewed as being dependent on developing evermore advanced industries. Thus, there has been an emphasis on enhancing industry's science base, as well as a shift in the concentration of R&D into newer industries. The concentration on R&D in drugs and medicines, computers, and electrical machinery has increased, while that in automotive industries, chemicals, and the basic metals industry of iron and steel has decreased (figure 16).

In the 1990s, Japanese manufacturing industries' leading R&D areas (as a proportion of total R&D) continued to be in communications technology (including consumer electronics and all types of audio equipment), motor vehicles, and electrical machinery. But from 1990–93, R&D expenditure levels in these industries decreased, as did their share of overall industrial R&D. In contrast, Japan began to increase R&D funding levels and R&D personnel in drugs and medicine (figure 16).

Japanese industry was among the first to restructure its manufacturing through offshoring to European, Asian, and North American countries. As with most of the offshore production and outsourcing now occurring in other industrialized countries, the major R&D activity has remained in the firms' central laboratories

Figure 16. Japanese manufacturing R&D: 1981 and 1993



1/ Excludes communication equipment.
2/ Excludes drugs and medicines.

See appendix table A-110 and A-12.

in Japan. These central laboratories will continue to work on R&D innovations, while some small amount of marketing research will be conducted abroad. (See "*Nissan Offshore Manufacturing"* as one example of this trend, with R&D maintained in Japan's industrial laboratories.)

To a greater extent than in the United States, industrial R&D expenditures in Japan are concentrated on electrical and non-electrical machinery, radio, television, and communications equipment (table A-13 and figure 17).

By 1993, drugs and medicine had the highest R&D expenditures as a percent of net sales at 9.9 percent, compared with motor vehicles at 2.7 percent, or petroleum and coal at 0.9 percent (table A-13 and figure 18). R&D by non-manufacturing industries in Japan still comprises less than 5 percent of industrial R&D.

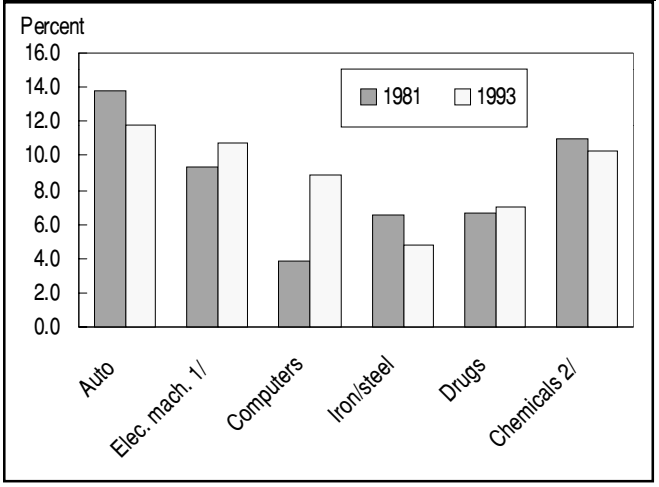
Nissan Offshore Manufacturing

To be free from money exchange rate problems caused by the sharp appreciation of the yen, Nissan has some production and R&D activity offshore. The production of automobiles abroad is mainly in the United States (Tennessee) and England, but also in Spain, Mexico, Thailand, Taiwan, and South Africa. Over 1,600,000 automobiles are produced in Japan; and 600,000 are produced abroad. The Tennessee facility produces 450,000 cars a year. The number of cars produced in England is restricted, but those produced are exported throughout Europe, and have 3 percent of the market share.

The main R&D facilities will remain in Japan, and Nissan central laboratories will continue the R&D necessary for cost reductions, such as low fuel consumption and low exhaust emissions. However, partial R&D work will be done abroad, in the United States and England, to design automobiles with local parts and local suppliers. To advance technology, some parts may be developed abroad. (Marumo, 1996).

While minimal research for particular companies will be conducted in the United States, opportunities exist for enhanced U.S.–Japanese collaborative R&D in the automotive industry. Discussions for collaboration are underway in the important area of intelligent highways. In the future, automobiles will be an even more intelligence-intensive product. Japan is collaborating with Europe and the United States on Intelligent Transport Systems (ITS) for automated highways of the future. One technical committee of the International Standards Organization (ISO) is working for standardization of these future intelligent systems. Five Ministries in Japan work on ITS, including among others, MITI, Construction, and Transportation. Japan's particular focus in automated highways is research on navigation systems for ITS (Maruma, 1996).

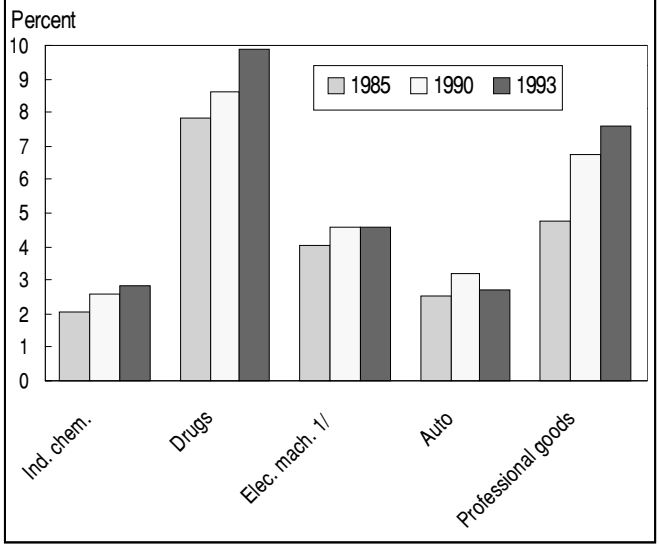
Figure 17. Proportion of R&D expenditures by selected industries: 1993



1/ Excludes communication equipment.
2/ Excludes drugs and medicines.

See appendix table A-12.

Figure 18. Japanese R&D expenditures as a percent of net sales: 1985, 1990, and 1993



1/ Excludes communication equipment.

See appendix table A-13.

U.S. leading R&D performers continue to be the aircraft and communications equipment industries, but these industries' share of overall industrial R&D fell during the last 10 years (NSB, 1996). In contrast, chemical industries, pharmaceutical companies, and companies primarily engaged in the manufacture of scientific instruments increased their share of industrial R&D. Far stronger growth, however, occurred in nonmanufacturing industries in the United States, which now account for more than 25 percent of industrial R&D. R&D performed by computer software companies and companies providing communication services are examples of these service sector industries.

Industrial Scientists and Engineers Engaged in R&D

Corresponding to the strong growth in industrial funding of R&D activity in Japan and in the United States in the 1980s is the almost equally strong growth in the number of industrial scientists and engineers engaged in R&D. In each country, the number of industrial scientists and engineers increased at an average annual rate of growth of more than 5 percent. However, Japanese industry continued to increase their employment of scientists and engineers for research and development despite their economic recession in the 1990s. In the United States, industry decreased its employment of scientists and engineers in R&D by about 25,000 from 1992–94 (table A-14).

Japan has more R&D scientists and engineers per 10,000 employees in manufacturing companies than the United States. In 1993, Japan employed 622 RSEs per 10,000 employees in manufacturing companies, compared with 520 RSEs per 10,000 in the United States in that same year. This higher employment of RSEs in manufacturing companies in Japan has existed since 1985 (table A-15).

Industry–University Relations

Compared with the university sector, Japanese industry dominates as the preferred place for research and advanced training. Industry particularly strengthened its research capacity in the 1980s by attracting and training top graduates from Japanese universities, as well as by expanding industrial research facilities. Japanese industry interacts with both domestic and foreign universities, especially those in the United States.

For example, Japanese industry sends its research personnel to top U.S. universities for 1 to 2 years for advanced study in particular fields. Previously, few Japanese students remained long enough at U.S. universities to complete a doctoral degree. Instead,

industrial researchers more likely returned to their company and earned a doctorate through corporate research. While Japanese industry continues to offer its employees the opportunity to earn their thesis doctorate through research in their corporate laboratories, U.S. universities also show recent small increases in the number of doctoral degrees in natural sciences and engineering earned by foreign doctoral candidates from Japan.[14]

Japanese industry is increasing its interaction with Japanese universities through donations and research contracts, and also is involved in the expansion of university-based doctoral programs. In the 1980s, some university professors worked jointly with industrial researchers on an area of strategic research under the ERATO programs. In the 1990s, Monbusho introduced Centers for Cooperative Research in Advanced S&T at some national universities in an effort to couple basic research in sciences with development activities in industry. Under this program companies send their researchers to complete a short Ph.D. degree useful to their R&D laboratory. For example, the interdisciplinary Research Center for Advanced Science and Technology (RCAST) at the University of Tokyo, which is a new Ph.D. program, receives many students from industry (researchers who have completed their master's degrees prior to employment). At RCAST, these doctoral students are required to switch to a field that is different from their master's program. Candidates enter fields in which their companies would like to expand research work. The cross-fertilization of different fields within a university-based doctoral program better prepares doctoral students to contribute to their company's new directions than does strictly within-industry training. Under the new 1996 basic research programs, industry now can conduct joint projects with university professors.

[14] Published tabulations of the U.S. Doctorate Record File do not show how many of the Japanese doctoral recipients are supported by Japanese industry.